Grand Canyon 2

1. You may recall from previous lessons that the late Proterozoic marked a time of supercontinent rifting.
2. About 1.2 billion years ago, rapid subsidence brought on by rifting led to the return of sedimentation - represented by the Grand Canyon Supergroup. As is usually the case with rift-related rock formation, the Grand Canyon Supergroup contains continental and shallow marine sedimentary rocks as well as volcanic and shallow intrusive igneous rocks.
3. Our study of the Basin and Range has shown us that rifting typically is associated with normal faulting and the formation of block faulted mountain ranges.
4. Subsequent erosion wore down the ranges such that the Grand Canyon Supergroup is preserved only within the somewhat tilted basins between the ranges. The broad, gently rolling Late Proterozoic landscape …
5. … was buried under thick sediments during the Paleozoic period by which time the region had become a full-blown Divergent Continental Margin.
6. Thus a “Great Unconformity” separates the Proterozoic rocks from the Paleozoic DCM sedimentary rocks.
7. The Great Unconformity can be recognized by the difference in tilt between the gently-tilted Proterozoic strata and the near-horizontal Paleozoic strata above.
8. What kind of unconformity is it?
9. Obviously it’s angular, right?
10. In certain places some of the Proterozoic Grand Canyon Supergroup rocks below the unconformity protrude through the Paleozoic rocks above the unconformity. This tends to happen with the Proterozoic Shinumo Quartzite because it is such a hard rock that when Late Proterozoic erosion occurred on the Grand Canyon Supergroup, small hills remained on the quartzite. When the Tapeats Sandstone was deposited, it did not completely cover up these hills, so the quartzite protrudes like “islands” out of an “ocean” of Tapeats Sandstone.
11. Above the Great Unconformity lies the “classic” Grand Canyon sequence of 10 sedimentary units that tell the tale of varied and intriguing primitive worlds.
12. Depositional environments varied markedly through time because sea and land levels rose and fell as the Supercontinent Cycle unfolded.
13. The Grand Canyon Sequence is mostly Paleozoic and records the depositional events that occurred on a divergent continental margin as Pannotia broke apart and Pangaea formed.
14. The general pattern of sea level change in the Paleozoic shows four periods when sea level rose …
15. … followed by four periods when sea level dropped.
16. Each time the sea rose, shorelines shifted inland, towards the center of the craton and deposition (shown in white here) covered more of the craton.
17. Such events are called transgressions.
18. Each time the sea fell, shorelines shifted away from the center of the craton – leaving it exposed to erosion.
19. Such events are called regressions.
20. The sedimentary record of each transgression/regression pair is known as a sedimentary cycle, or more specifically, a cratonic sequence if the sediments deposit on a craton. Four such sequences are recorded in the Grand Canyon Paleozoic section. There are also Mesozoic and Cenozoic cratonic sequences in North America, but they are not relevant to our study at this time, because they are not preserved in the Grand Canyon, nor did they form when western North America was a DCM.
21. The four Paleozoic cratonic sequences are represented by ten formations in the Grand Canyon, the first letter of which is found in the handy mnemonic: “Know The Canyon’s History Study Rocks Truly Made By Time”. Let’s take a closer look at the first sequence – the “Made By Time” group.
22. The first time the shoreline advanced toward land was the most profound.
23. It roughly corresponds to the Cambrian period, when sediment transfer into the oceans from the peneplanation of Pannotia and rapid sea floor spreading due to its subsequent rifting, combined to produce what might be described as the greatest transgression in earth history.
24. By the Middle Cambrian, the Grand Canyon area was awash in shallow seas.
25. A sandy shoreline lay to the east …
26. … while mud settled in slightly deeper water …
27. … and lime accumulated near the edge of the continental shelf. These of course are the classic sediments of a divergent continental margin, and when lithified became the rocks sandstone, shale and limestone.
28. The Tapeats is the sandstone, the Bright Angel is the shale, and the Muav is the limestone. Remember “Made By Time”. Sandstone is on the bottom because as sea level rose, a sandy shoreline was the first marine depositional environment to replace the peneplain eroded onto the Proterozoic basement. Sandy shorelines were replaced by deeper water mud and lime deposits as the depth and distance to the shore increased.
29. The Great Unconformity is most clearly seen between the light colored Tapeats Sandstone and the much darker Vishnu schist, but because the Vishnu schist is a metamorphic rock, such portions of the Great Unconformity are not considered angular unconformities. What kind of unconformity is this?
30. Did all you *nonconformists* get it right?
31. Here is an artist’s conception of the near shore environment represented by the Tapeats Sandstone. The critters are trilobites – *the* quintessential Cambrian fossil.
32. That the Tapeats Sandstone was deposited in a shallow, near-shore environment, is evidenced by lens-shaped bodies created by tidal currents, …
33. … and that it pinches-out against resistant Proterozoic topographic highs or islands (notice how thin the unit is at “A”) …
34. … just like modern sandy beaches do.
35. Notice the dark, shaly rock above the Tapeats Sandstone.
36. Name that shale!
37. Here’s a subtle hint.
38. You are truly amazing! How do you do it?!
39. Because the Bright Angel Shale is weak and easily eroded, it cannot maintain cliffs like the more durable sandstone and limestone units.
40. Instead, it forms the conspicuous, broad shelf above the Inner Gorge known as the Tonto Platform.
41. Good exposures only occur on the Lower Grand Canyon, where the Bright Angel Shale is in contact with the Colorado River which continuously removes the rock as fast as it disintegrates.
42. Deposited in a shallow, muddy sea, more offshore than the Tapeats Sandstone, the Bright Angle Shale contains a correspondingly different fossil assemblage which includes worm burrows, brachiopods and jellyfish in addition to the requisite Cambrian trilobites.
43. The culmination of the first transgression is represented by the Muav Limestone. Now that the Cambrian shoreline had reached it’s furthest inland position, the Grand Canyon region was now perhaps 300km from that shoreline in relatively deep water, where very little land-derived clastic sediment existed. In these clear ocean waters shell-building creatures flourished and limestone deposited.
44. Here we see the Muav Limestone on the Kaibab Trail, the shortest path to the river from the south rim, and therefore very popular. Due to iron staining from the Redwall Limestone above, the Muav Limestone is generally much redder than it would be by its self.
45. This is especially true at Royal Arch. The spectacular sight can only be reached by a far less accommodating trail than the Kaibab.
46. In fact, the route to Royal Arch …
47. … is considered one of the most difficult in the canyon …
48. … and requires advanced scrambling and climbing skills.
49. I can tell you with absolute certainty that I will never hike this trail!!!!
50. The exposure is insane!
51. Apparently the magnificent arch creates a cathedral-like setting that for skilled adventurers is worth the risk.